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SnapTrack/GTEW/Sprint PCS

GPS-Assisted Location Technology
Alpha trial Field Test in Tampa, FL
Mar 9th - Apr 2, 1999.

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Presentation topics

- ✓ Test objectives
- ✓ Test Limitations
- ✓ Test Environment
- ✓ Test participants
- ✓ Test architecture
- ✓ Test plans & results
- ✓ Host Carrier (GTEW, Sprint PCS) observations & remarks
- ✓ Areas for further analysis
- ✓ SnapTrack recommendations for improvement

Test Objectives

- ✓ Validation of the SnapTrack technology in live CDMA networks, focussing on the E911 Phase II requirements
- ✓ Benchmark Sensitivity & Accuracy
  - Evaluate "Test Plan" applicability and validity
  - Varying topographical conditions
  - Varying GPS satellite constellation geometry
  - Stationary, Pedestrian, 10-55 mph user
- ✓ Compare "Yield" and "Sensitivity"
  - CDMA Network-integrated handset Vs non-integrated SnapTrack sensor
- ✓ Various antenna prototypes
- ✓ Handsets from various vendors
- ✓ Get a feel for "total integration"

Test limitations

- ✓"Data" calls only - no concurrent Voice capability (current CDMA limitation)
- ✓Data transport using IS-99 Circuit switched CDMA protocols
- ✓All handsets may not have SnapTrack GPS Sensor boards completely integrated
- ✓Limited Urban Canyon, no mountainous terrain, and no basements in the Tampa area

Test Environment

- ✓ Tampa, FL and suburbs
- ✓ 34 test cases, some executing multiple times with different antennae and time of day ==> **9000 location fixes** over a 3.5 week period. (7am to midnight testing)
- ✓ GTEW 800 MHz and Sprint PCS 1900 MHz networks
- ✓ Motorola 800 MHz and Samsung 1900 MHz handsets
- ✓ External M/A-COM, External Patch, External Helix, Internal Patch GPS antennae configurations
- ✓ Concurrent SnapTrack stand-alone sensor testing using QCP820 phones as a test sanity check

Test Environment (cont)

- ✓ Network-integrated sensor:
  - Receives time-of-day and base station ID from the handset
  - Uses CDMA carrier as a reference frequency source to calibrate its oscillator
  - Uses input-blanking scheme to protect handset transmitter injecting noise into the GPS receiver
- ✓ Network-integrated sensor may or may not be mechanically integrated into the handset. Motorola handset had the sensor mechanically integrated. Samsung had not yet.
- ✓ Other than the reference M/A-COM external GPS antenna, other antenna prototypes were built on the sensors. Antennas were tuned for user positions against their heads, while most tests did not have the head-blockage. Four major tests were conducted specifically for side-by-side antenna testing, all done by the head.

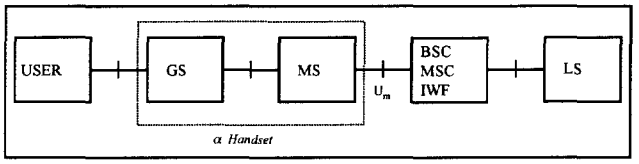
Test Environment (cont)

- ✓ M/A-COM antenna characteristics
  - External
  - About 8db better than the Internal Patch antennas
- ✓ M/A-COM antenna Usage, Antenna was positioned at:
  - Automobile headrests - 30 mph and 55 mph tests
  - On the top of an automobile - Parking Garage tests
  - On the pedestrian shoulder - Pedestrian tests

Test Participants

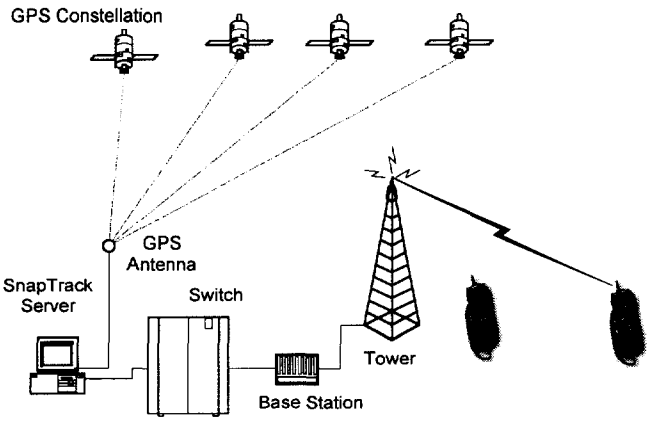
- ✓ SnapTrack - overall project integrator/project manager
- ✓ GTEW - Host network for 800 MHz
- ✓ Sprint PCS - Host network for 1900 MHz
- ✓ Motorola - 800 MHz handsets
- ✓ Samsung - 1900 MHz handsets
- ✓ Others waiting in the wings: Hyundai/Cyberlane, LGIC, Motorola 1900 MHz

Test Architecture



- ✓ **USER:** The role of the user is to operate the handset and initiate a call. The net result of the call is to display at the LS system the handset position on a map. The call is a data-only call using IS-99 circuit-switched data services on a live CDMA network. There is no voice call directly associated with the location call. It should be noted that USER interacts solely with the MS, i.e., via keypad.
- ✓ **GS:** This is the SnapTrack Enhanced GPS Sensor prototype. Functionality and features are as in the current SnapTrack Sensor Prototype 2 generation board. Basic plan is to "loosely couple" in a single form factor one GS with one typical MS: the alpha handset unit.
- ✓ **MS:** This is an IS-95A digital mode wireless handset with IS-99 circuit-switched data support. Other options include QuickNet Connect feature. MS keypad and display support the interface to USER.
- ✓ **BSC/MSC/IWF:** For the purposes of this discussion, all CDMA network elements between MS and LS (not inclusive) are lumped. The purpose of the CDMA network in the alpha technical trial is to provide an asynchronous, circuit-switched data connection, per IS-99 specification.
- ✓ **LS:** This is the SnapTrack Location Server. The Location Server will support an interface to the IWF and also to an external mapping application, which can be used to display handset location data in real time

Test Configuration



Test plans

- ✓ Alpha test plan derived from the CDG GPS/GPS-assisted test plan submission
- ✓ Alpha test plan "adapted" to the Tampa geographical area
- ✓ Test sites selected by SnapTrack with GTEW/SPCS assistance
- ✓ Ground truth for the test sites predetermined
- ✓ No Ground truth available for moving tests

Test Results reporting

- ✓ Performance of Network-integrated (3G Sensor) Vs non-integrated (2G Sensor)
- ✓ Reference antenna (M/A-COM) Vs Prototype antennae (small patch internal, small patch external, small helix from Symmetricom)
- ✓ Accuracies quoted in both 1-sigma (67% cdf) and 2-sigma (95% cdf)
- ✓ All data is for **cold-start**, **single-fix** attempts

Test results reporting (cont)

- ✓ "Yield":
  - Defined as a ratio of the number of successful fixes to the total number of attempts
  - Most of the test steps conducted for 200 data points
  - Goal is for yield to be very close to 100%.
- ✓ "Accuracy":
  - Raw results reported as "Lat" and "Long"
  - Raw results plotted as Scatter diagrams
  - 1-sigma reported in meters. This value depicts the radial error from the ground truth of 67% of the result measurements
- ✓ The FCC E911 Phase II mandate requires 1-sigma to be within 125 meters.

Test 2: Rural site

- ✓ To measure reference performance in "Open" locations including testing next to a cell tower
- ✓ Determine base station proximity effect
- ✓ Basically a non-demanding environment
- ✓ 1400 location attempts, 2 failures (attributable to software timing issues)
- ✓ 3G performance matched 2G performance
- ✓ "Yield" was 100% for all except Test 2B (98%)
- ✓ 1-sigma ranged from 3.4 to 8.4 meters

Test 4: Inside Stationary car

- ✓ Results obtained for 3 time periods for satellite constellation variation
- ✓ Tests emulate usage environments for a typical large number of users
- ✓ Morning period shows some impact of poor satellite visibility
- ✓ "Yield" ranged from 98% to 100%
- ✓ 1-sigma ranged from 8.6 to 17.0 meters

Test 5: Inside Stationary car, Antenna comparisons

- ✓ Prototype antennas on the Motorola (3G) phone held against driver's right side of the head during the test calls
- ✓ The 2G reference phone sat by the inside right shoulder of the driver
- ✓ 3G Symmetricom and the Small Ext. Patch antennas produced similar results, which are slightly degraded compared to the 2G reference phone, explaining some of the head blockage impacts.
- ✓ "Yield" was 100% for all three tests
- ✓ 1-sigma ranged from 9.2 to 15.7 meters

Test 6: Inside parked car in narrow alley, Antenna comparisons

- ✓ Test area was the narrowest, tallest alley available in downtown Tampa.
- ✓ Prototype antennas held against right side of the driver's head
- ✓ The 2G reference phone sat by the inside right shoulder of the driver
- ✓ 3G Symmetricom performed much better than the Small Ext. Patch.
- ✓ "Yield" ranged from 80% to 100%
- ✓ 1-sigma ranged from 37.1 to 71.7 meters

Test 7: Inside car (30 mph), Motorola (3G) with M/A-COM antenna

- ✓ "Yield" ranged from 98% to 100%
- ✓ Due to the mobility of the tests, prerecorded ground truth was not practical
- ✓ Location plots against street map are available for both the reference 2G receiver and the 3G test receiver
- ✓ Based upon map street centerlines, and assuming reasonable map accuracy, reported locations were within 10-20 meters

Test 8: Inside car (55 mph), Motorola (3G) with M/A-COM antenna

- ✓ "Yield" was 100% for all the tests
- ✓ Due to the mobility of the tests, prerecorded ground truth was not practical
- ✓ Location plots against street map are available for both the reference 2G receiver and the 3G test receiver
- ✓ Based upon map street centerlines, and assuming reasonable map accuracy, reported locations were within 10-20 meters

Tests 9 & 10: Stationary pedestrian on suburban sidewalk

- ✓ "Yield" was 100% for all the tests
- ✓ 1-sigma ranged from 7.4 to 11.9 meters
- ✓ Accuracies were within the above range for all antenna configurations and traffic loading periods

Test 11: Outside pedestrian - Walking

- ✓ "Yield" was 100% for all the tests
- ✓ Due to the mobility of the tests, prerecorded ground truth was not practical
- ✓ Location plots against street map are available for both the reference 2G receiver and the 3G test receiver
- ✓ Based upon map street centerlines, and assuming reasonable map accuracy, reported locations were within 10 meters

Tests 12A/B/C: Inside wood/masonry residence, 1st floor of 2-story house

- ✓ Morning, Afternoon, Evening time periods for the 3G with reference antenna
- ✓ Comparative tests with 2G had very little difference with test results of the 3G
- ✓ "Yield" was 100% for all the tests
- ✓ 1-sigma ranged from 22.8 to 25.8 meters

Test 12D: Inside wood/masonry residence, 1st floor of 2-story house

- ✓ Antenna variations for an inside residence environment
- ✓ Free space yield was 100% with the 3G reference antenna
- ✓ Held against the head, Yield dropped to 88% with the 3G Small Ext. Patch antenna
- ✓ Accuracy for the above cases was in the 26-28 meters range
- ✓ Symmetricom antenna for the same configuration yielded only 63% with 1-sigma dropping to 41 meters.

Tests 12E and 13: Inside wood/masonry residence, 1-story house with Metal roof

- ✓ Test location had a metal roof, with the expected blockage of all the direct path overhead signals
- ✓ 1st floor test results of the 3G reference show yields of 84-94% and accuracies of 31-33 meters
- ✓ 1st floor test results of the 2G reference had similar yield and accuracies (99%, 29 m)
- ✓ Basement test results with the reference antenna varied with time periods: 58-98% yield and 26-50m accuracy
- ✓ Prototype antenna performance in the basement for single fix yields was poor (patch 41%, Symmetricom 31%). Usable location determination is probable with multi-fix approaches.

Test 14: Inside shopping mall, 1st floor

- ✓Similar 2G and 3G results
- ✓Yield was 100% in all test cases
- ✓1-sigma ranged from 25.2 to 35.2 m

Test 15: Inside 2-3 story office building, interior location (Univ.. of S. Fla)

- ✓Heavily blocked commercial indoor environment
- ✓2G and 3G results very similar
- ✓Yield ranged from 75% to 80%
- ✓1-sigma ranged from 33.8 to 36.1 m
- ✓Multi-fix approach may help to increase the yield percentages

Tests 16 and 17: Multi-story parking garage, center, 2 floors from the top, many cars, phone on car roof

- ✓ Tests were at an interior location away from the edge
- ✓ Similar 2G and 3G results
- ✓ Yield ranged from 82% to 100%
- ✓ 1-sigma ranged from 20.2 to 25.4 m
- ✓ Performance not significantly affected by the number of cars. Shielding effect of the car surfaces perhaps compensated by increased reflective surfaces for the GPS signals

Tests 18: Urban canyon, 25-50 story buildings, 4-lane street, sidewalk, mid-block

- ✓ 100% yields in the morning 3G and 2G tests. 1-sigma of 2G (72m) better than 3G (82m)
- ✓ Stronger west bias in 3 of the 3G runs, requires further analysis
- ✓ Evening and night tests yielded 10% degradation
- ✓ Several "outlying" fixes require further analysis

Test 19: Urban canyon, 4-lane street, on sidewalk, mid-block, next to human head

- ✓ Antenna comparison tests for this environment
- ✓ Yield ranged from 94% to 100%
- ✓ 1-sigma ranged from 49.7 to 75.4 m

Tests 20: Middle floor of 25-50 story office building

- ✓ Tests done interior of the 50-story glass/steel office building on the 20th floor
- ✓ **Windows with metallic coating**
- ✓ Very high signal attenuation
- ✓ Poor single-fix performance in the interior hallway requires further analysis
- ✓ Several 2G/3G performance discrepancies require further analysis

SnapTrack's preliminary conclusions

- ✓ No significant yield or accuracy performance difference between 2G and 3G (network-integrated), except for the 50-story office building tests
- ✓ Above implies that the extraction of TOD, Base Station ID and carrier frequency source from the network (via the handset) is paying off
- ✓ Some reduction in sensitivity of the small handset-sized antennas relative to the reference antenna. However, performance gap is getting smaller and some handset antenna prototypes are already achieving acceptable performance levels
- ✓ The Snaptrack GPS technology can be successfully incorporated into a compact handset package

SnapTrack's preliminary conclusions (cont)

- ✓ All tests were single, standalone, cold start fixes -- **absolute worst case scenario**. Multi-fix which was developed after the alpha development, will improve yield and precision

Motorola Concerns/Caveats

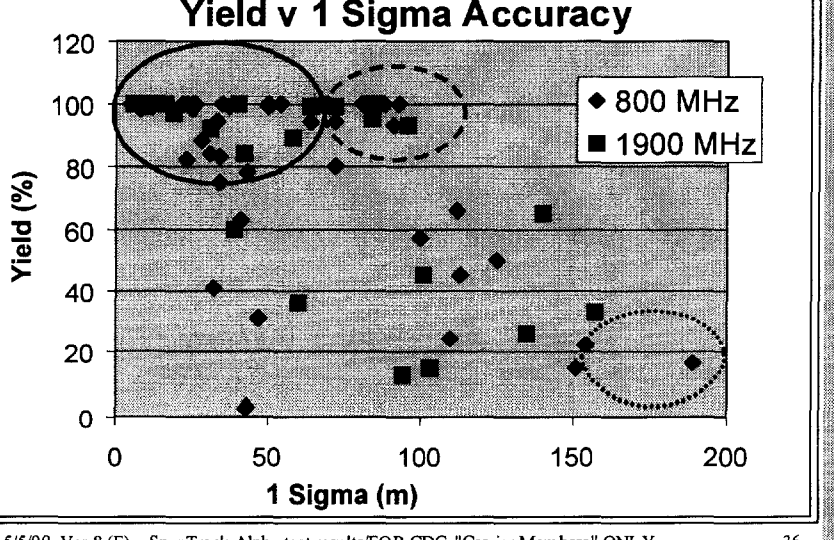
- ✓ Of the Network supplied parameters, Base Station ID was not utilized.
- ✓ The small handset-sized antennas' performance was comparable to the larger GPS reference antenna, ONLY under "Open Sky" conditions. In fact, "solutions with handset-sized antennas will not be able to match larger sized GPS antennas" for in-building.
- ✓ Even though "Multi-fix" approach may improve the yield and precision, TTFF may also degrade.

GTEW's observations

- ✓ Pleased with the "outdoor" test results. Share Motorola's concerns for difficult "in building" environments
- ✓ Several growing pains, Snaptrack/Motorola have been actively resolving:
  - Sensor power glitches
  - Server software glitches
  - Handshake problems requiring re-start of the tests
  - Minor mechanical integration glitches

Samsung/Sprint PCS Testing

- ✓ Fewer tests were completed at 1900 MHz
- ✓ Only one antenna used besides the M/A-COM
- ✓ Results overall, support the conclusion:
  - Implementing this technology, over different bands, different manufacturers, different antennas, different generations, yielded results suitable for demanding location applications including E 9-1-1



Conclusions - "No Bad News"

- ✓ 1900 MHz and 800 MHz produced similar results
- ✓ Green (solid) area - high performance data, "very good indeed", under 50 m in bulk of the cases
- ✓ Yellow (dashed) area - Where the yield is over 80%, FCC accuracy criterion is met
- ✓ Red (dotted) area - where yield is poor, accuracy still bounds the location measurement to prevent RMS blow-up

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TR45.5 Location Standards Update

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Purpose

- To provide an update on the current and planned activities within TIA TR45.5 related to location service standards

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Outline

- Background & Activities to Date
- Current Activities
- Short Term Plans
- Future Activities & Evolution
- Questions & Discussion

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Background & Activities to Date

- Ad Hoc group formed in Nov '98 to merge the multiple proposals received from manufacturers (Lucent Tech., Motorola, Nortel, Qualcomm, SnapTrack)
- Object: Develop an open standard accommodating various technologies/techniques to ensure interoperability

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Background & Activities to Date (cont.)

- Strong manufacturer participation. Weekly/bi-weekly conferences calls & meetings. 100+ contributions reviewed to date.
- Clear, up-front guidance from carrier community a key factor

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Background & Activities to Date (cont.)

- **Nearing completion of "point-to-point" protocol & procedures**
  - **Backward compatible with TIA/EIA-95-B -- uses Data Burst Message**
  - **Signaling transported on traffic channels. Effort to accommodate paging/access channel signaling as well in initial version of standard**
- **Initial version of the standard sufficient for E911 location**
  - **Follow-on activities to enable/enhance other location services**

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Background & Activities to Date (cont.)

- **Supported technologies/techniques**
  - **Enhanced Forward Link Triangulation (pilot phase)**
  - **Assisted GPS**
  - **Autonomous GPS**
  - **Auxiliary/External GPS**
  - **Hybrid (GPS & pilot phase)**

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Current Activities

- Parameters Ad Hoc conference calls being conducted to resolve few remaining open issues
- Signaling Ad Hoc conference calls being conducted to develop baseline standards text by May 17th TR45.5 meeting

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Short Term Plans

- "Point-to-point" baseline text for May TR45.5 opening plenary (May 17)
- V&V baseline text during May meeting
- Ballot text at conclusion of May meeting

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Future Activities & Evolution

- **Location Parameters Ad Hoc will continue to meet to address broadcast mode procedures (assist info broadcast on paging channel)**
  - **Enhancement for E911**
  - **Enabler for CDMA Tiered Services & other location services**
- **Following definition of broadcast parameters & techniques, develop signaling and rev initial standard**

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TR45.5 Location Standards Update

Questions?

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